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# LOWER COOK INLET HERRING FORECAST FOR 1992

By

Henry J. Yuen

and

Wesley A. Bucher

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## AUTHOR

Henry J. Yuen is Region II Lower Cook Inlet Research Biologist for the Alaska Department of Fish and Game, Division of Commercial Fisheries, 333 Raspberry Road, Anchorage, AK 99518.

Wesley A. Bucher is Region II Lower Cook Inlet Area Management Biologist for the Alaska Department of Fish and Game, Division of Commercial Fisheries, 3298 Douglas Street, Homer, AK 99603.

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## ABSTRACT

During 1991, inclement weather conditions prevented aerial assessment of the Pacific herring *Clupea harengus pallasi* run biomass in the Kamishak Bay District of Lower Cook Inlet. Therefore, run biomass was estimated as the difference between the 1991 preseason forecast of run biomass (18,565 tons) and the 1991 commercial harvest (1,992 tons). Age and weight data obtained from harvest samples were used to convert the estimated biomass into numbers of herring. The 1992 forecast was based on the same age specific estimates of natural mortality, recruitment, and growth used to prepare the 1991 forecast. The 1992 Kamishak Bay District herring population is forecasted to have a run biomass of 16,431 tons, and be largely comprised of three age groups: 4, 8, and 9 year old herring. The 10% harvest rate being used to allow the population to rebuild will allow a projected harvest of 1,643 tons.



KEY WORDS: *Clupea harengus pallasi*, Pacific herring, forecast, Lower Cook Inlet, Kamishak Bay, mortality

# INTRODUCTION

The Lower Cook Inlet Management Area consists of all waters within three miles of the shore west of the longitude of Cape Fairfield in the Gulf of Alaska, north of the latitude of Cape Douglas in Shelikof Straits, and south of the latitude of Anchor Point in Cook Inlet. This management area is subdivided into four management districts: Kamishak, Southern, Outer, and Eastern.

Early commercial Pacific herring *Clupea harengus pallasi* harvests in Lower Cook Inlet were used for production of fish oil and meal. These harvests began in 1914 with a gill net fishery to supply salteries in the Southern District (Kachemak Bay). Purse seines were introduced into this fishery in 1923. Harvests reached a peak between 1924 and 1926 and then sharply declined as the herring population in this area collapsed. Purse seine fishing shifted to the Eastern District (Resurrection Bay) in 1939. Harvests in this area reached a peak between 1944 and 1946, and then declined as this population collapsed during the late 1950s. Herring abundance has remained low in the Southern District, but has increased in the Eastern District in recent years.

Today most commercial herring are harvested in Lower Cook Inlet for their roe, a specialty item marketed in Japan. The first commercial roe harvests in Lower Cook Inlet occurred in the Eastern and Southern Districts in 1969. However, in 1973 fishing effort shifted to Kamishak District. During 1978 the Kamishak Bay herring biomass declined to only 1,202 tons and the entire Lower Cook Inlet roe fishery was closed in 1980. Kamishak, Eastern, and Outer Districts were reopened to fishing in 1985. The Kamishak District harvest peaked in 1987 at 6,132 tons when the total spawning biomass was estimated to be 35,332 tons. The Eastern and Outer Districts were again closed to fishing in 1990, and the Southern District was reopened only during 1989. Currently, all of the Lower Cook Inlet roe harvest is taken in Kamishak District. Roe recovery rates have always been greater in Kamishak District than in the other districts. This has probably been due to the occurrence of a larger proportion of older, larger herring in Kamishak District, whose population is currently dominated by herring from the 1983 and 1984 year classes. In contrast, Eastern district population samples have rarely contained herring older than age 4.

The objective of this report was to document methods used to produce the 1992 Kamishak District forecast of herring run biomass and projected harvest included within the statewide herring report (Funk and Harris 1992). The present report also includes an alternative estimate of 1991 spawning biomass based on revised year class tables which were not available for the 1992 Kamishak District forecast included within Funk and Harris (1992).

## METHODS

The Kamishak District herring forecast has been based on the previous year's run biomass, estimated from aerial surveys within the district, adjusted for fishing mortality, natural mortality, growth, and recruitment. Aerial surveyors were not able to estimate run biomass in 1991 due to inclement weather which restricted flying opportunities and limited water visibility. Therefore, the 1992 forecast was based on the 1991 forecasted run biomass rather than 1991 aerial observations. For this report, run biomass was defined as the spawning herring population within the district during mid-April to June.

### *1991 Run*

Although the 1991 run biomass was predicted to be 17,256 tons (Yuen et al. 1990), only 3,665 tons were observed by aerial surveyors. Therefore, the 1992 forecast was based on a 1991 run biomass estimated by expanding actual aerial survey results. The 1991 commercial harvest (1,992 tons) was estimated from fish tickets obtained from buyers. Age composition of the 1991 harvest was used to partition the 1991 run into component age groups:

$$N_i = p_i N \quad . \tag{1}$$

where:

$N_i$ = number of age-*i* herring in total run;
$p_i$ = proportion of age-*i* herring in harvest samples;
$N$ = number of herring in total run.

The 1991 run remaining after commercial removals (escapement) was also partitioned into age group estimates:

$$E_i = N_i - C_i \quad . \tag{2}$$

where:

$E_i$ = number of age-*i* herring in escapement, and
$C_i$ = number of age-*i* herring in total harvest.

### *1992 Run Forecast*

An exponential decay model was used to predict the 1991 and 1992 run for each age group:

$$N_{i,t}=E_{i-1,t-1}e^{-(M_{i-1}-R_{i-1})} , \quad (3)$$

where:

$t$ = spawning year;
$M_i$ = instantaneous natural mortality rate for age-*i* herring;
$R_i$ = instantaneous recruitment rate for age-*i* herring.

While recruitment can be thought of as occurring only once during each year, since all mature herring migrate inshore to spawn where they were available to the roe fishery, we expressed recruitment as an instantaneous rate since we were not interested in separating the effects of $R_i$ from $M_i$:

$$(M_{i-1}-R_{i-1}) = -\left(\frac{\ln N_{i,t}}{E_{i-1,t-1}}\right) . \quad (4)$$

The value of $(M_i-R_i)$ was positive whenever age-*i* herring were fully recruited (i.e. mortality of age-*i* herring exceeded gains through recruitment). Prior to full recruitment the value of $(M_i-R_i)$ was negative. Since new data were not obtained during 1991, estimates of $(M_i-R_i)$ for the 1992 forecast were the same values used the previous year (Yuen et al. 1990).

*Growth*

The mean weight of an individual herring within each age group was estimated from harvest samples. Mean annual growth for each age group was estimated with the same regression model used for the 1991 forecast (Yuen et al. 1990):

$$w_{i,t} = 51.95681 + 0.80805(i-1) + 0.79462w_{i-1,t-1} , \quad (5)$$

where:

$w_{i,t}$ = mean weight of age-*i* herring at time of spawning in year *t*.

Growth in weight for each age group was used to convert estimated numbers into estimated biomass of herring:

$$B_{i,t} = N_{i,t}w_{i,t} , \quad (6)$$

where:

$B_{i,t}$ = biomass of age-*i* herring at time of spawning in year *t*.

Biomass estimates for individual age classes were then summed to determine total biomass of the spawning population:

$$B_t = \sum_{i=3}^{16} B_{i,t} \quad , \tag{7}$$

where:

$B_t$ = total run biomass at time of spawning in year *t*.

### *1992 Harvest Projection*

Concern with low recruitment and a declining population biomass (e.g. Bucher and Morrison 1991) prompted the department to set the 1992 Kamishak District total allowable harvest equal to 10% of the forecasted run biomass. The total allowable harvest will be divided between the Shelikof Straits winter bait fishery (10%) and the Kamishak Bay spring roe fishery (90%).

### *Probability of Obtaining the Forecasted Run*

To estimate the probability of obtaining the forecasted 1992 run biomass, a predicted run biomass value was calculated for each of the nine years within the data set using a cross validation technique. This entailed omitting data for the prediction year from the forecast model prior to calculating a prediction for that year. Once forecasts were made for each year, the ratio between the predicted and observed run was calculated for each year in the data set:

$$\frac{B_{observed}}{B_{predicted}} \quad . \tag{8}$$

Although only nine cross validation estimates were available, a discrete frequency distribution was produced by sorting ratio values into three categories: 1) prediction greater than observed run biomass (ratio value less than one); 2) prediction equal to observed run biomass (ratio value equal to one); 3) prediction less than observed run biomass (ratio value greater than one). Frequency of occurrence of ratio values within each category were then expressed as a percentage of the total number of years for which forecasts were made.

## RESULTS

A run biomass of 16,431 tons of herring is expected to occur within Kamishak District in 1992. Total allowable harvest is projected to be 1,643 tons. Allocation of the projected harvest was 1,479 tons for the Kamishak District spring roe fishery and 164 tons for the Shelikof Straits winter bait fishery (Table 1). Mean weight of individual herring is expected to be 214 g. The run biomass is expected to be dominated by three age groups: age-4 (29%), age-8 (34%), and age-9 (11%) herring from the 1988, 1984 and 1983 year classes, respectively (Table 2).

Observed run biomass during the past nine years has ranged from about 40% to 300% of cross validation predictions. The frequency distribution of ratio values was very skewed: forecasted run biomass was less than observed run biomass in six out of the nine years examined. These results suggested that there is only a small chance, 11%, that the observed run biomass will be less than the forecasted run biomass in 1992, but a large chance, 67%, that the observed run biomass will exceed the forecasted run biomass.

## DISCUSSION

The run biomass of Kamishak District herring reached a peak in 1987 and has been declining since that year. The department has tried to maintain harvest rates ranging from 10% to 20% of run biomass for Kamishak District herring since 1985. Generally, a 10% harvest rate was used for age-4 and younger herring while a 20% harvest rate was used for age-5 and older herring. However, to allow Kamishak District herring run biomass to rebuild, a 10% harvest rate has been used for all age groups since 1990 (Bucher and Morrison 1991). A 10% harvest rate will again be applied in 1992 unless aerial surveys indicate that run biomass is well above the forecasted biomass.

After initial forecast results were published in Funk and Harris (1992), estimates of instantaneous natural mortality, instantaneous recruitment, growth, age composition, and the 1991 escapement were revised based on 1) correction of errors in age and size data sets from past years, 2) development and use of a composite age composition model to estimate run biomass age composition, and 3) development and use of an aerial survey probability model to estimate run biomass during years having limited aerial survey coverage. These changes have been described and documented in a report being published within the Technical Fishery Report series by Yuen et al. (*in press*) and will be used in forecast models for 1993.

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Table 1. Harvest allocation of 1992 Kamishak herring run biomass.

| | Exploitation Rate | Harvest (tons) |
|---|---|---|
| Kamishak District Roe Fishery | 9% | 1,479 |
| Shelikof Straits Bait Fishery | 1% | 164 |
| Total | 10% | 1,643 |

Table 2. Kamishak District herring abundance forecast and harvest projection by age class, 1992.

| Age (i) | 1991 Escapement ($E_{i-1}$) | Instantaneous Mortality and Recruitment ($M_{i-1}$-$R_{i-1}$) | 1992 Population Forecast (x1,000) | Proportion by Number | 1992 Predicted Mean Wt (g) | 1992 Run Biomass Forecast (tons) | Harvest Rate | 1992 Total Allowable Harvest | Proportion by Weight |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 7,241 | -1.12 | | | | | | | |
| 4 | 4,993 | 0.01 | 22,193 | 0.29 | 116 | 2,840 | 0.10 | 284 | 0.17 |
| 5 | 5,938 | 0.07 | 4,943 | 0.06 | 151 | 825 | 0.10 | 82 | 0.05 |
| 6 | 7,094 | 0.10 | 5,536 | 0.07 | 195 | 1,191 | 0.10 | 119 | 0.07 |
| 7 | 29,542 | 0.13 | 6,419 | 0.08 | 218 | 1,540 | 0.10 | 154 | 0.09 |
| 8 | 10,857 | 0.29 | 25,941 | 0.34 | 228 | 6,529 | 0.10 | 653 | 0.40 |
| 9 | 1,882 | 0.50 | 8,124 | 0.11 | 268 | 2,399 | 0.10 | 240 | 0.15 |
| 10 | 3,111 | 0.70 | 1,141 | 0.01 | 277 | 348 | 0.10 | 35 | 0.02 |
| 11 | 1,230 | 0.97 | 1,545 | 0.02 | 284 | 484 | 0.10 | 48 | 0.03 |
| 12 | 652 | 0.95 | 466 | 0.01 | 301 | 154 | 0.10 | 15 | 0.01 |
| 13 | 432 | 1.66 | 252 | 0.00 | 300 | 83 | 0.10 | 8 | 0.01 |
| 14 | 147 | 1.64 | 82 | 0.00 | 313 | 28 | 0.10 | 3 | 0.00 |
| 15 | | 0.00 | 28 | 0.00 | 312 | 10 | 0.10 | 1 | 0.00 |
| Total | 73,119 | | 76,672 | | | 16,431 | | 1,643 | |
| Weighted Mean | | | | | 214 | | | | |